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ON-FARM WEATHER STATIONS

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(This paper is an expanded form of an article 'On-Farm Weather Stations - an Automatic Choice' that appeared in 'Crops' magazine, summer 1987).

AWS's - Automatic Weather Stations - are not new. For a number of years researchers and meteorologists have used them to get vital weather data from remote and uninhabited places. Unmanned observing stations in the Cairngorms, monitor the strongest winds encountered in the British Isles through the bitterest Scottish winters, while at sea instrumented buoys face everything from flat calms to Force 10 gales as they faithfully gather crucial weather information and relay it to land via satellite.

AWS's for use on land were first considered reliable enough by the early 1970s to be used for operational purposes by the Meteorological Office, and the first operational marine AWS was deployed in the southwest approaches in 1978. Because of the requirement for high reliability, an AWS for operational use for a met service takes many man years of development, and is inevitably expensive. A Met Office synoptic AWS (SAWS), now installed at about 22 locations, costs about £30,000 while a marine AWS costs hundreds of thousands of pounds per year to buy and operate. But just as computers were at one time affordable only by large organisations but are now cheap enough to buy for the home, so commercial AWS's are available at prices which make them attractive to many farmers. Clearly a couple of thousand pounds would not buy you a SAWS, but there are some good quality products available with sophisticated electronics that, properly maintained, will give many years of reliable service on a farm. There are also some cheaper products available which might seem adequate for your immediate needs, but which might prove disappointing in the longer term. This article aims to help you examine your needs for on-farm weather information, and how you can effectively meet that need in the simplest, cheapest and most convenient way.

Do I need an AWS?

Basically an AWS is simply a means of measuring weather and there have been ways of doing that ever since Man first learned to lick his finger and hold it above his head. So before you begin to consider an AWS you must first of all answer the question: what weather information do I really need?

If it is a simple requirement for a particular weather element then traditional instruments may be sufficient. For example, wind speed to aid spraying or straw burning decisions, or air temperature to guide management of a potato store would be satisfied by a simple hand-held anemometer and a thermometer on a convenient north-facing wall.

A little more sophistication is required if several different pieces of weather information are needed; evaporation, for example, would need measurements of sunshine, windspeed, temperature and humidity. Then you

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might consider localising the sensors at a particular well chosen site, with the information being displayed in a convenient place, or places. The measurements would typically comprise wind speed and direction, rainfall, air temperature and humidity, and perhaps some measure of sunshine. You would then have a weather station. Providing you choose the instrument site well, that is on flat ground away from buildings and not in shade, the measurements you made there would be valid for similar sites on the rest of your farm. The Meteorological Office Observer's Handbook (HMSO, 1982) gives guidance on the exposure of instruments. Table 1 shows the typical variation with distance of meteorological variables measured at 2 metres. (The question of variation in microclimate will be discussed later). All the variables except rainfall vary only slowly with distance so you can be confident that a measurement at one site will be representative of conditions over a radius of several kilometres. Because rainfall is the exception farmers have always been recommended to install their own raingauges if rainfall is required for, say, soil moisture calculation. Even on an individual farm daily rainfall can vary widely between fields on showery days, though weekly totals on all except very large or very hilly farms should be similar.

If your need for meteorological information was sufficient to justify a weather station, what other considerations might encourage you to pay the extra for an automatic weather station? Here an AWS is defined to be a weather station which is able to do at least one of the following.

. Gather data at set times or intervals and record these data either on a printer or on some storage medium.

. Manipulate the measured data to produce useful information, for example the growth stage of a cereal crop, the evaluation evaporation over the last week or the risk of potato blight development.

. Produce signals that can be used to control other farm operations.

Daily weather data

The simplest AWS would provide a printout of weather data either as a continuous chart or as a printout at preset intervals. This can not only save a lot of time you would otherwise spend reading instruments but can also provide a detailed record of weather that might add valuable management information. For example when exactly did the rain start - was it long enough after spraying for the herbicide to take effect?

Printouts are great when they consist of only a few day's data, but quickly turn into a headache when they accumulate over weeks and months. It might seem a shame to throw out such information, but unless you have an efficient means of storing and, more important, of accessing these historic records then it may be best simply to discard them.

The problem of storage is eased if the data can be recorded on tape or or on a disk, but not the problem of access. For that you will need a computer that can read the information and a program that will manipulate the data to produce averages, totals or extremes. So if you have visions of building up a climatology of your farm then beware: there can be much

hidden expense and frustration down this road. If you need to know weather statistics for your farm it is simpler and cheaper to approach the Met Office, who hold extensive weather records for your area and who are able to quickly extract the information you need. (ADAS has Met Office staff at each of its regional headquarters).

With an on-board microprocessor an AWS can do more than simply record. It can check the raw data and 'flag' data that look odd. It can perform calculations on the data to produce anything from averages and totals, to indices that depend on a combination of the measurements, such as wind chill, evaporation or the risk of disease spread.

Disease prediction

It is this last application of disease risk assessment which seems to be the selling point for many on-farm AWS's, and there is no doubt that this is one of their major strengths. Figure 1 compares the actual course of an infection of eyespot on winter wheat with the theoretical pattern predicted from weather data a) from on-site measurements and b) from the nearest Met Office synoptic station. The greater precision of the local data is obvious, though the more remote data still gave useful guidance. So, if you have a high value crop where the cost of an AWS is outweighed by the potential loss of failing to check the disease outbreak or by the cost of spraying unnecessarily, then an AWS is called for. However the graph does not necessarily prove the general case in favour of AWS's.

First, weather-based indices should always be used in conjunction with an assessment of the present state of disease in a crop, never on their own. So an in-field AWS will not remove the need to walk the field. Also in practice the poorer performance of the remote data is partly rectified because indices derived from Met Office weather stations are combined with ADAS assessments of current plant disease status around the country before they are published.

Second the graph demonstrates that individual fields have their own individual microclimate, which differs from the macroclimate to an extent that depends on slope, aspect, soil, local topography and on the crop itself, and that to monitor accurately conditions for disease spread you should monitor that microclimate. But where do you stop? Do you buy an AWS for each field? And within an individual field there are often different microclimates. How do you cope with this diversity without spending a fortune?

The possible answer is to recognise the strengths of the well exposed weather station whether it is an official Met Office site, or your own on-farm version. Such a station is designed to monitor the overall weather, and not to be greatly influenced by some local feature. So while it will not tell you conditions in, say, a low lying field, it does give a record of weather which experience and common sense can relate to the many microclimates of your farm.

A final point on the subject of disease indices. Some AWS's are sold with several disease indices programmed in, but it is not always easy to extract from the makers the details of the scientific research on which these indices are based, as they may be regarded as commercial secrets. It

is very important that the method used to calculate the indices is valid for your proposed use. For example if some original research related the development of Bloggs Brown Blight disease to weather at the nearest meteorological station, then you will not necessarily get the right answers if you use an in-field AWS to predict the spread of BBB.

An AWS as a controller

The third aspect of an on-farm AWS is to use its output as a control signal. At the most sophisticated level the AWS could feed information to the farm computer, which could then make some calculations and if necessary control farm operations (perhaps even send signals to your 'thinking tractor'). But unless your operation is already highly automated and computer-oriented, such as an environmentally-controlled glasshouse, you would find that the extra equipment required to integrate the AWS into an automated system would be very expensive.

Choosing an AWS

If you decide you really do need an AWS what should you look for in your proposed purchase? Aircraft designers have a fundamental rule: first the engine, then the airframe. An equivalent rule for weather station makers should be: first the sensors, then the electronics. As evidenced by the home computer, the cost of sophisticated electronics has plummeted over recent years as a result of the widespread production and application of microchips. The same factors have not affected meteorological sensors such as anemometers which are low volume, hand-made items and consequently relatively expensive. They can always be made cheaper of course but the British climate will soon find any weaknesses, particularly if waterproofing is not 100%.

Most AWS firms buy-in equipment from various suppliers, and it is rare for a company even to make all its own sensors. As with cattle, pedigree is important. Look for the manufacturer or distributor who has experience in environmental instruments. Measuring the weather always looks like the easiest thing in the world, and it takes field experience to be convinced otherwise: reliable measurements only come from careful thought, good engineering and the best materials.

A visual examination of the instruments should help you assess the quality though some may be of an unfamiliar pattern. (For a more detailed treatment of environmental sensors see Fritschen and Gay, 1979 or Woodward and Sheehy, 1983).

Wind speed and directon

The traditional cup anemometer and wind vane remain the most popular devices; they are simple, reliable and you can see at a glance if they are working properly. Look for a starting speed when 'run-in' of around 0.2 ms^{-1}, but beware of anything that looks flimsy or whose construction might allow rain to reach the bearings. The signal produced by the anemometer is either a continuous voltage, or a stream of pulses whose frequency is proportional to wind speed. The wind vane often provides a step-wise change in output as wind direction varies, with the width of the 'steps' being typically 10-15° of wind direction, though it may be as small

as 1°. Some more sophisticated instruments measure wind speed through its effect on heat loss or on the pressure distribution around a special sensor.

Temperature

A thermistor or a platinum resistance thermometer (PRT), protected from the sun by a screen, are popular and perfectly adequate air temperature sensors. PRTs offer stable calibration and a resistance that varies linearly with temperature, though their relatively small signal places high demands on the associated electronics. Thermistors provide a much larger, though non-linear signal per unit change in temperature. Early thermistors were subject to alarming drifts in calibration, but they are now more stable and finding increasing application in areas once dominated by the PRT. Drawing air past the sensors usually improves accuracy but requires extra power to drive the aspirating fan; for most farm applications a well screened, unaspirated thermometer is generally adequate.

Humidity

The traditional wet and dry bulb hygrometer remains one of the best methods of measuring humidity, though its accuracy depends on careful maintenance of the wick and its water supply. The tedious conversion of wet and dry bulb temperatures to the required humidity parameter may be done automatically by the AWS. Solid state devices that sense relative humidity directly (often by a change in the sensor's electrical capacitance) are found increasingly in AWS's. They are increasingly reliable but do not yet match the durability of a well-maintained wet- and dry-bulb, particularly under conditions of prolonged high humidity. Dew-point sensors can be very accurate but their relative complexity rules out their widespread use in weather stations.

Sunshine

Solarimeters (sometimes known as pyrehliometers or pyranometers) measure only the short wavelengths between 0.3 and μm ie the visible part of the spectrum plus a bit on either side. This region contains Photosynthetically Active Radiation (PAR) so a solarimeter is appropriate for monitoring light levels for glasshouses. Net radiometers measure the difference between downward and upward radiation of all wave lengths, so monitor the total energy input to the soil or crop by radiation. They would be appropriate for calculation of, say, evaporation.

Rainfall

This ought to be the easiest variable to measure but in practice it is not; careful study shows that wind blowing across a gauge can produce large errors in the amount of rainfall collected. The design of the gauge should also minimize any evaporation of the collected water. It is also prudent to have a filter to keep out foreign objects such as insects and leaves. All these points are incorporated in raingauges that follow established Meteorological Office practice. A 'tipping bucket' system is often used to measure the actual amount of precipitation. Because this produces a count each time 0.1 or 0.2 mm of rain is collected, rainfall intensity can be

inferred from its records. One commercial system counts the water-drops as they flow through a small hole at the base of the collector, but this depends on the drops being of uniform size and on rainfall not being sufficiently intense to cause the collector to overflow.

Leaf wetness

Leaf wetness is not a true meteorological variable since it depends on the properties not just of the atmosphere but also of the leaf - orientation, aspect and type of leaf surface. But because many plant pathogens thrive in wet surroundings it is often an important variable to measure.

Sensors are normally designed to mimic the physical and thermal characteristics of a leaf, with the wetness state of the surface being detected by the resistance between a series of fine, interleaved strips of conducting material. Even if a sensor faithfully replicates a real leaf, one sensor cannot reproduce the wetness of all the leaves in the corresponding crop. Clearly some compromise must be reached in the placing of the sensor such that it represents an average value for the crop, and two or three sensors within the crop itself would yield better results.

Pressure

This is not generally supplied as part of an AWS, though it is available on some as an optional extra - at considerable cost. It is ironic that the barometer - the traditional tool of amateur and professional weather forecasting - is absent from today's sophisticated AWS's. So even if you do buy an AWS, keep that barometer hanging in your hall.

Connectors

Under sensors we must include the electrical connectors to the sensors. Unless connectors are inside a weatherproof box and never likely to encounter condensation, then they should be of a military specification for outdoor use. The cost of these connectors is high - as much as £50 or more - and this is a tempting area in which to cut costs, but anything less will eventually allow dampness to penetrate and corrosion to start.

Electronics

Often the electronics package will be a data logger that is used in other industries so again, try to assess pedigree by talking to other users. The complexity of the electronics depends on what you want the AWS to do. Remember that the more flexibity you want in its operation the more complicated it will be to program.

If you want a simple printout in what format will the information be presented? Can you control how frequently it will take measurements? If you want the display or the printout in an office 200m from the AWS, do you simply need a long cable or will the signal need to be boosted? If the AWS accumulates data is it in a form that other computers can read and interpret? Is software available for your computer that allows you to analyse the data?

If the AWS also performs calculations of indices additional questions should be asked about the formulae that are used internally for these calculations. Have they been verified by field experiments? Are the formula appropriate to your circumstances?

If the AWS is to be used for control purposes or to communicate with other computers you need to ask questions about compatibility. Does it already have interfaces that allow it to communicate with a wide variety of other devices, for example can it use a modem to send data down a telephone line?

The quality of a piece of electronics is difficult to assess by visual examination but at least judge what you can see: the box. Is it strong? Is it waterproof? What precautions have been taken against condensation? Will the buttons and keys stand up to use on the farm?

Costs

Automatic weather stations are not cheap. One manufacturer reckons that a basic set of instruments would cost a minimum £1000 - excluding electronics. Reliable electronics to log, store and transmit the data would bring the total cost to between £2000 and £3000, and this figure is representative of a number of stations on the market. For this price you would measure temperature and humidity, wind speed and direction, sunshine and rainfall - but not barometric pressure. For that you might need to add another few hundred pounds.

Whatever a salesman might try to tell you any weather station will need maintenance if its records are to be reliable over long periods. The world is an unfriendly place for instruments left out on cold, dark nights or frosty days. Atmospheric pollution, rabbits, birds, driving rain and little boys with catapults all demand that periodic checks are made on the equipment. So you must include labour costs in your accounting. And if you decide to go for a complex system linked to your farm computer you will need to allow for software and manpower to quality control, store and access the meteorological data.

Table 2 shows a comparison of costs for running your own weather station and for obtaining similar data from the Met Office. The figures suggest that a simple on-farm weather station is an attractive way of providing immediate, local weather information for day-to-day use, if you are prepared to devote the effort to maintenance. On the other hand if you have ambitions to generate your own weather archive, perhaps even working in co-operation with nearby farms then beware of the large overheads which this will incur, and the same amount of money could buy you a considerable amount of advice from professional meteorologists with access to a great deal more weather information.

An AWS can provide timely, local and accurate weather information which can be used to guide day-to-day decisions about valuable and weather-sensitive crops or operations. Though expensive to buy it is likely that, under the right circumstances, an AWS can pay for itself perhaps even in as

little as one season. The question of whether your farm represents the right circumstances demands careful consideration on your part and a realistic assessment of the real costs of operating an AWS.

References

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Table 1

Variation of meteorological variables measured at a height of 2m

Meteorological element	Horizontal variation	Vertical variation
Temperature	Varies little over distances of 100km. Exceptions: at the coast in on-shore winds; in urban areas; near fronts	Average decreases of 0.6c with each 100m of altitude. Exceptions: may increase with height for the first few metres on clear, still nights or in frost hollows and valleys.
Humidity	Varies little over distances of 100km. Exception: near fronts	Similar to air temperature
Wind	Varies little over distance of 100km. Exceptions: In hilly or sheltered areas at the coast; near fronts	
Rain	Extremely variable over a wide range	Increases on windward slopes
Sunshine	Daily totals vary by 5-10% over distances of 100km, though generally sunnier near coats and in the lee of mountains.	Decrease, on average, with altitude due to increased cloudiness

Table 2. Comparison of estimated annual costs of single on-farm AWS and meteorological data from the Met Office.

On-farm AWS	£	Met Office	£
A. Current data			
Equipment purchase (3000 over 5 years at 10%)	900	Daily telex of data from nearest synoptic stations	2700
Maintenance contract (10% of purchase price)	300	or	
Labour (recording data)	150	Weekly Weather Notes plus ADAS Bulletin	230
or		Labour (logging messages and keying into computer)	150
Dedicated microcomputer and interfaces to log automatically (£3000 over 5 years)	900	Microcomputer to store and process data (£1000 over 5 years)	300
sub-total - max	2100	sub-total - max	3150
- min	1350	- min	680
B. Climatological data			
Software for quality control, and data storage (£500 over 5 years)	150		
Software maintenance (5% of cost)	25		
Software for retrieval and analysis of data	300		
Labour (storing monthly data on disk - 1 hour/ month)	30		
Consumables (floppy discs, paper)	10		
10 accessions to stored data (15 mins/accession)	6	10 accessions to 'Weather Statistics' package (incl. time on phone)	160
Sub-total	521	Sub-total	160
Total A + B	max 2621		max 3310
	min 1871		min 840

Fig. 1 EYESPOT INFECTION OF WINTER WHEAT

—— observed - - - modelled from on-site data
..... modelled from nearest synoptic station data

(from Schroedter, 1983)